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Hydrocarbons on Saturn's Satellites: Relationship to Interstellar Dust and the Solar Nebula

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To understand the origin and evolution of our Solar System, and the basic components that led to life on Earth, we study interstellar and planetary spectroscopic signatures. The possible relationship of organic material detected in carbonaceous meteorites, interplanetary dust particles (IDPs), comets and the interstellar medium have been the source of speculation over the years as the composition and processes that governed the early solar nebula have been explored to understand the extent to which primitive material survived or became processed.

The *Cassini* VIMS has provided new data relevant to this problem. Three of Saturn's satellites, Phoebe, Iapetus, and Hyperion, are found to have aromatic and aliphatic hydrocarbons on their surfaces. The aromatic hydrocarbon signature (C-H stretching mode at 3.28 μm) is proportionally significantly stronger (relative to the aliphatic bands) than that seen in other Solar System bodies (e.g., comets) and materials (*Stardust* samples, IDPs, meteorites) and the distinctive sub-features of the 3.4 μm aliphatic band (CH_2 and CH_3 groups) are reminiscent of those widely detected throughout the diffuse ISM.

Phoebe may be a captured object that originated in the region beyond the present orbit of Neptune, where the solar nebula contained a large fraction of original interstellar ice and dust that was less processed than material closer to the Sun. Debris from Phoebe now resident on Iapetus and Hyperion, as well as on Phoebe itself, thus presents a unique blend of hydrocarbons, amenable to comparisons with interstellar hydrocarbons and other Solar System materials.

The dust ring surrounding Saturn, in which Phoebe is embedded, probably originated from a collision with Phoebe. Dust ring particles are the likely source of the organic-bearing materials, and perhaps the recently identified small particles of Fe detected on Saturn's satellites.

Lab measurements of the absolute band strengths of representative aliphatic and aromatic molecules, together with measurements from the VIMS data, allow us to calculate the number of C atoms to find the *relative abundances* of C atoms in the two kinds of organic molecules. The strength of the prominent aromatic C-H stretch band relative to the aliphatic band complex in Phoebe and Iapetus indicates that the relative abundance of aromatic to aliphatic carbon is very large (>200). In contrast, the aromatic band is nearly imperceptible in spectra of interplanetary dust particles (IDP), returned samples from comet 91P/Wild 2, insoluble carbonaceous material in most meteorites, and the diffuse interstellar dust (DISM) (although aromatics are known in all these materials—here we consider only the spectroscopic signature).

The material from which Phoebe formed is likely a combination of native interstellar ices, minerals, metal (e.g., Fe) and solid organic matter, plus an unknown fraction of the same material processed in the solar nebula. The dominant form of carbon in interstellar ice depends primarily on competition between CO hydrogenation ($CO + H \rightarrow CHO$), and CO oxidation ($CO + O \rightarrow CO_2$) on grain surfaces. The HCO radical produced in the first reaction readily undergoes further reactions to the organic molecules H_2CO, CH_3OH, and others. The second reaction produces CO_2, in which the carbon is sequestered in a tightly bound molecule that tends to inhibit further chemical changes. The apparent high abundance of CO_2 in the composition of Phoebe, Iapetus, and Hyperion, and the absence of H_2CO and CH_3OH, thus discriminates between two paths of chemical evolution of the materials from which they accreted.

In addition to ices, interstellar dust carries hydrogenated amorphous carbon and polycyclic aromatic hydrocarbons (PAHs); together these are the dominant carriers of carbon. The presence of both aromatic and aliphatic hydrocarbons on Phoebe, Iapetus, and Hyperion supports the view that Phoebe accreted from outer solar nebula materials. The organic molecules, low-albedo dust, and Fe particles found on the three satellites may represent original interstellar material that was largely unaltered in the solar nebula.